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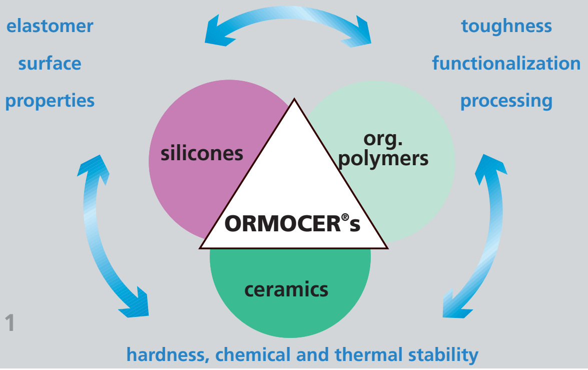

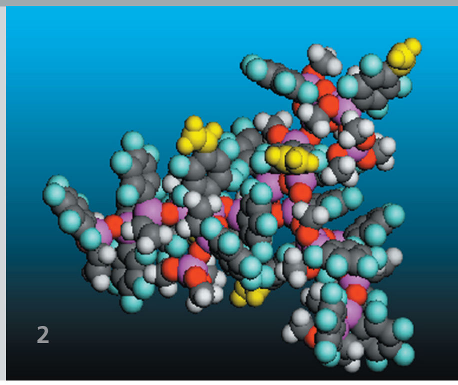

1 *ORMOCER®s and their relation to other materials*
2 *Visualization of an ORMOCER® oligomer based on NMR spectra and HyperChem and COMPASS force-field methods*

INORGANIC-ORGANIC HYBRID POLYMERS (ORMOCER®S) FOR MICRO SYSTEMS TECHNOLOGY

Motivation

Micro systems are generally highly-integrated compact systems which combine sensor and actuator as well as other intelligent properties. A further increase in integration density is achieved by a continuous decrease in structural dimensions in electronic, optical or optoelectronic devices. A significant decrease in device dimensions, however, leads to the need of high-performance materials for packaging which can meet the high requirements for patternable materials:

- Micro- and nanostructuring
- Compatibility to conventional packaging technology
- Functionalization
- Economy

The material

ORMOCER®s can combine the properties of glasses and ceramics, organic polymers and silicones (Figure 1). The ORMOCER® material properties can be tailored trough the composition and the amount and kind of educts.

Material synthesis

ORMOCER®s are inorganic-organic hybrid polymers which are synthesized in a first step by sol-gel processing (schema overleaf). By catalytically controlled hydrolysis/polycondensation of organically modified (R'_x) metal alkoxides, e. g. $R'_xSi(OR)_{4-x}$, a partially inorganic network is built up by the formation of organically functionalized inorganic-oxidic oligomers (sol/resin). In a second step, these can be thermally and/or photochemically (UV) cross-linked due to the organic functionalities R'_x, whereas R'_x can be a styryl-, methacryl-, acryl- and/or an epoxy-group. Finally, after thermal curing of the functional layers, microstructures or bulk materials are obtained.

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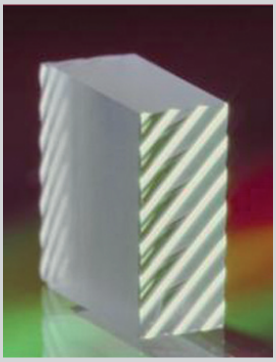

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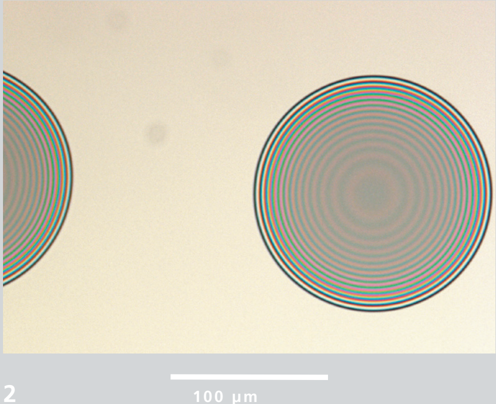

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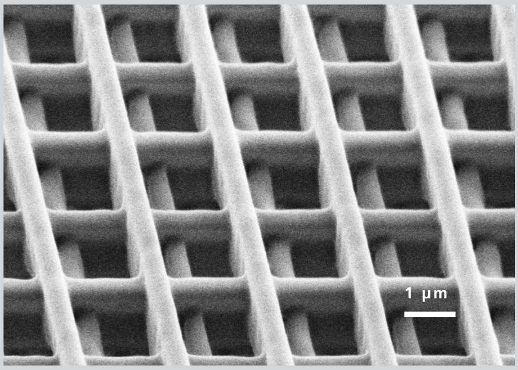

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Characterization

The physical/chemical properties of ORMOCER®s can be tuned by the kind and the concentration of non-polymerizable functional groups (network transformers) as well as by the configuration of the inorganic and organic network. The latter, however, can be influenced in a broad range by the choice and synthesis of educts. This yields a tremendous amount of innovative applications. The Table demonstrates some selected material properties from the broad material spectra. Due to the chemical binding to various substrates and to their low water uptake, ORMOCER®s demonstrate very good passivation properties.

Application

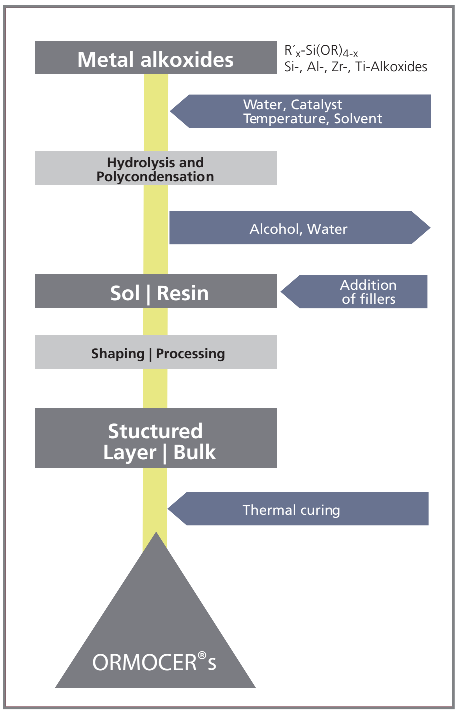
ORMOCER®s can be applied by spin-on, dipping, backfilling and curtain coating on a variety of different substrates such as Si/SiO_2 wafers, glasses, polymer substrates like, for example, FR4 (glass-fiber reinforced epoxides) or even flexible polymer substrates or foils. Particularly, the use of FR4 allows one to perform extensive mass production using projection exposure and an increase of the integration density of individual modules with a back-side contact using ball grid arrays. Their low curing temperatures between 100 °C and 170 °C make them attractive not only for polymer substrates, but also with respect to temperature-sensitive devices.

Patterning

Due to their outstanding material proper-ties, one and the same material can be used for dielectric multi-layers and stripe waveguides, respectively. The patterning of ORMOCER®s at ISC is usually performed in a clean room (class 100 to 10 000).

ORMOCER®s behave like negative resists which can be patterned by photolithography, two-photon polymerization with femtosecond lasers, or direct laser writing, which allows one to produce periodic and non-periodic structural features. Also, laser ablation and embossing techniques are applied for the production of optical devices with ORMOCER®s. Due to the very good adhesion properties of ORMOCER®s on metals, one can easily produce multilayers for electronic, optical and electro-optical applications.

Schematic demonstration of materials synthesis and processing



Selected materials properties of ORMOCER®s	
Refractive index n (@ 635 nm)	1.44 - 1.59
Thermooptical coeffient	-4 to $-1.5 \cdot 10^{-4}$ K^{-1}
Optical loss (non-fluorinated systems)	< 0.1 dB/cm < 0.2 dB/cm < 0.55 dB/cm
Coefficient of thermal expansion α	$60 ... 250 \cdot 10^{-6}$/K
Thermal curing	≤ 150 °C
Permittivity ε_r (in the range GHz-Hz) without filler	2.5...6
Dielectric loss factor tanδ (in the range GHz-Hz)	$3.5 \cdot 10^{3} ... 1 \cdot 10^{2}$
Specific resistance ρ	> 10^{16} $\Omega \cdot$cm
Dielectric strength (e.g. Cu)	200 - 400 V/ µm
Degradation (TG)	up to 400 °C
Soldering stability	270 °C/>1 min
E-Module	MPa - GPa (adjustable)
Water uptake	< 0.5 %

1 *Array of confocal microlens telescopes, fabricated by double-sided UV replication (courtesy of Fraunhofer IOF)*

2 *ORMOCER® microlenses, fabricated by ink-jet printing*

3 *3D photonic crystal structure, fabricated using ultra-short laser pulses (515 nm)*